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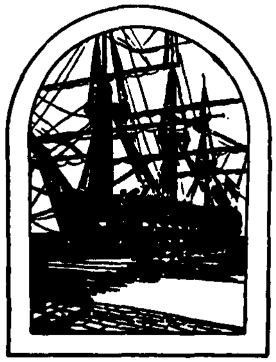

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C.D.L. REPORT

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THE CORROSION OF STAINLESS STEELS AND RELATED ALLOYS IN MARINE ENVIRONMENTS

PART II. RESULTS FOR FURTHER ALLOYS

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SYNOPSIS

The corrosion behaviour of a number of stainless steels and high nickel alloys, additional to those given in C.D.L. Report GCF (ACC/N 196/59 (H 405)) are reported. The precipitation hardenable stainless steel FV.520, of particular interest due to its high strength, had only slightly improved corrosion resistance compared to the martensitic stainless steel En.57. The austenitic alloy Langalloy 11K behaved similarly to a normal ferritic steel with respect to the form of attack but with a reduced corrosion rate. No stainless alloy tested can be recommended to withstand full immersion crevice corrosion conditions.

INTRODUCTION

Since reporting the corrosion behaviour of commonly used stainless steels and high nickel alloys (1) a number of similar alloys, including a proprietary precipitation hardenable stainless steel, have been tested for their corrosion behaviour. The previous report concluded that such alloys had good intrinsic corrosion resistance in well aerated sea water but they were liable to severe local corrosion under crevice conditions. In the present series of tests it was the resistance to crevice corrosion which was principally investigated.

II. EXPERIMENTAL

The testing methods used involved an accelerated laboratory test for crevice corrosion, crevice corrosion tests in Langston Harbour, and plain corrosion tests in respect of one alloy. Accelerated tests were confined to specimens in bar form and comprised martensitic stainless steels, including a proprietary precipitation hardenable steel, austenitic stainless steels, chromium plated stainless steel, Nimonic 80, and Stellites. The Langston Harbour tests comprised similar stainless steels and a number of high nickel alloys. Plain corrosion tests were made on the proprietary manganese-aluminium austenitic steel Langalloy 11K.

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In the accelerated test specimens, in bar form, were locally depassivated electrolytically and crevices quickly formed using tight polythene sleeves before exposure in a tank of sea water for 3 weeks. With this method, the time interval between depassivation and forming the crevice must be extremely short, otherwise the oxide film will re-heal.

The crevice corrosion tests in Langston Harbour were made under full immersion conditions, the exposure period being one year. The crevice was made by sandwiching half a 3 in. x 1 in. specimen between two pieces of perspex as described previously(1).

The plain corrosion specimens of the proprietary alloy Langalloy 11K were tested in the cold worked, annealed, and oxidised conditions (1 hour at 600°C in oxygen). In addition, the steady corrosion potentials of this alloy in sea water were measured with reference to a saturated calomel electrode.

III. RESULTS

Using the accelerated crevice corrosion test it was apparent that the martensitic stainless steel En.57 and the precipitation hardenable stainless steel FV.520 were readily susceptible to crevice corrosion regardless of the heat-treatment. Chromium plate up to a thickness of 4 thou. failed to prevent crevice corrosion as shown in Fig. 1. The results of this test for a number of alloys are shown in Table 1.

The extent of crevice corrosion on specimens exposed for one year in Langston Harbour are given in Table 2. It will be seen that all the martensitic stainless steels and monel were severely attacked. Austenitic stainless steels and high nickel alloys, other than monel, were only slightly attacked with the molybdenum containing alloys En.58J, FV.254 and Hastelloy 'C' giving the best results.

The plain corrosion rates of the Langalloy 11K after one years exposure and the measured corrosion potentials are shown in Table 3. It will be observed that the corrosion potential of Langalloy 11K is similar to that of mild steel (- 0.65 volts) rather than a stainless steel (-0.1 to 0.2 volts) and consequently it is unlikely that the Langalloy 11K would be susceptible to crevice corrosion.

In the crevice corrosion tests the Langalloy 11K and the Corronel 'B' (66 Ni/28 Mo/6 Fe) corroded outside the creviced area.

IV. DISCUSSION AND CONCLUSIONS

The results given for further martensitic and austenitic stainless steels and high nickel alloys should be considered as an Addendum to C.D.L. Report GCP (ACC/N 196/59, ACC/H 405/59). The conclusions given in the earlier report are supported and in particular it may be noted that the precipitation hardenable stainless steel FV.520 behaved similarly to the martensitic steel En.57.

Apart from this general conclusion it may be noted that the crevice corrosion resistance of the hardenable stainless steels (En.57, and FV.520) varied significantly according to structure as well as chemical composition and that chromium plating had no beneficial effect.

Molybdenum bearing stainless steels were least attacked in the austenitic group and of these Rex 78 and FV.254 appeared to be slightly superior to En. 58J. The hard facing alloys (Stellites 1, 6 and 12) were comparable to austenitic stainless steels in their resistance to crevice corrosion.

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In the high nickel alloys Ni-O-Nel and Hastelloy 'C' had much superior crevice corrosion resistance to Monel. Corronel 'B' was attacked outside the crevice and suffered a higher plain corrosion rate than other nickel alloys, tested under these conditions.

The austenitic alloy Langalloy 11K suffered general corrosion and behaved similarly to a mild steel with a third of the corrosion rate. The corrosion potential of this alloy (-0.79) is less basic than mild steel (-0.65 volts) and the possibility of its use coupled to aluminium alloys is being investigated.

Reference

(1) The Corrosion Resistance of Stainless Steels and Relative Alloys in Marine Environments.

C.D.L. Report GCF (ACC/N 196/59, ACC/H 405/59).

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TABLE 1

SUSCEPTIBILITY OF ALLOYS TO CREVICE CORROSION
LABORATORY TESTS

MATERIAL	HARDNESS V.P.N.	% COMPOSITION NOMINAL MAJOR ALLOYING ELEMENTS				EXTENT OF ATTACK
		C	Cr	Ni	Others	
MARTENSITIC STAINLESS STEELS						
En.57	258	0.16	16.5	2.4		Severe
En.57	300	0.16	16.5	2.4		Severe
FV.520 Soft	232	0.07	16	6	1½ Cu, 1½ Mo.	Severe
FV.520 Peak Hardness	392	0.07	16	6	1½ Cu, 1½ Mo.	Severe
FV.520 Overaged	310	0.07	16	6	1½ Cu, 1½ Mo.	Severe
AUSTENITIC STAINLESS STEELS						
En.58 J	-	0.07	18	10	3 Mo.	Very slight
En.58 F	-	0.08	18	10	1½ Cb.	Slight
G. 18 B	-	0.4	13	13	2 Mo, 2½ W, 10 Co, 3 Cb	Slight
FV.254	-	0.07	18	18	3½ Mo, 2½ Cu, ½ Ti	None
Langalloy 20V	-	0.04	20	30	3½ Mo, 4 Cu, 1 Cb	Slight
Rex 78	-	0.7	14	18	3½ Mo, 3½ Cu, ½ Ti	None
HIGH NICKEL ALLOY						
Nimonic 80	-	0.04	21	75	2½ Ti, ½ Al.	Severe
HARD FACING ALLOYS						
Stellite 1	-	-	34	-	43 Co, 14 W, 9 Fe.	None
Stellite 6	-	-	33	-	55 Co. 6 W, 7 Fe.	Slight
Stellite 12	-	-	34	-	47 Co. 10 W, 9 Fe.	Slight

/Table 2.

TABLE 2

CREVICE CORROSION RATES OF STAINLESS STEELS AND HIGH NICKEL ALLOYS

TESTS IN LANGSTON HARBOUR

MATERIAL	HARDNESS V.P.N.	% COMPOSITION NOMINAL. MAJOR ALLOYING ELEMENTS				CREVICE CORROSION RATE	
		C	Cr	Ni	Others	mg./crev. sq.dm./day	Average
MARTENSITIC STAINLESS STEELS							
En.57 Soft	252	0.16	16.5	2.4		42.2, 47.6, 37	42.3
En.57 Heat treated	348	0.16	16.5	2.4		41.8, 35.2, 35.2	37.4
FV.520 Soft*	232	0.06	14.4	5.3	$1\frac{3}{4}$ Cu, 2 Mo.	16.4, 17.8, 7.8	14.0
FV.520 Peak Hardness*	385	0.06	14.4	5.3	$1\frac{3}{4}$ Cu, 2 Mo.	11.2, 24.4, 13.8	16.5
FV.520 Overaged I*	301	0.06	14.4	5.3	$1\frac{3}{4}$ Cu, 2 Mo.	37.6, 17.0, 30.0	29.2
FV.520 Overaged II*	315	0.06	14.4	5.3	$1\frac{3}{4}$ Cu, 2 Mo.	27.4, 40.0	33.7
AUSTENITIC STAINLESS STEELS							
En.58J As Received	263	0.07	18	10	3 Mo.	0.02, 0.04, 0.46	0.2
En.58J Annealed	187	0.07	18	10	3 Mo.	0.6, 5.4, 5.4	3.8
FV.254	150	0.07	18	18	$3\frac{1}{2}$ Mo, $2\frac{1}{2}$ Cu, $\frac{1}{2}$ Ti	0.02, 0.02, 0.08	0.04
Langalloy 20V	223	0.04	19.7	29.6	$3\frac{1}{2}$ Mo, 4 Cu, 1 Cb	5.4, 7.0	6.2
HIGH NICKEL ALLOYS							
Monel	130	0.1	-	69	1 Fe, 30 Cu	16.6, 14.6, 16.6	15.9
Ni-O-Nel As Received	242	1.75	21	40	31 Fe, 3 Mo, $1\frac{3}{4}$ Cu	0.4, 3.8, 0.6	1.6
Ni-O-Nel Annealed	194	1.75	21	40	31 Fe, 3 Mo, $1\frac{3}{4}$ Cu	0.2, 3.0, 1.6	1.6
Hastelloy 'C'	210	-	15	58	17 Mo, 4 W, 6 Fe	0.03, 0.04	0.04

*Heat treatments:

Soft	1050°C Air Cooled
Peak Hardness	1050°C Air Cooled + 2 hours 750°C + 24 hours 15°C + 2 hours 450°C Air Cooled.
Overaged I	1050°C Air Cooled + 2 hours 750°C Air Cooled + 24 hours 15°C + 2 hours 560°C Air Cooled.
Overaged II	1050°C Air Cooled + 2 hours 850°C Air Cooled + 5 hours 450°C Air Cooled.

TABLE 3

THE CORROSION RATES AND CORROSION POTENTIAL OF LANGALLOY 11K

(C. 0.59, Si. 0.12, Mn. 22.05, Al. 8.80, Ni. 0.05, P. 0.020, S. 0.025, Fe. rem.)

Condition	Hardness VPN/30	Corrosion Rate mg./sq.dm./day		Corrosion potential with reference to saturated calomel half cell volts
		Individual Results	Average	
Cold Worked sheet	375	9.1, 9.9	9.5	-0.79
Annealed sheet	287	8.8, 10.0	9.4	-0.79
Oxidised sheet	-	10.0, 15.5	12.6	-0.61

Corrosion rate of mild steel 30 mg./sq.dm./day
Corrosion rate of copper 8 mg./sq.dm./day

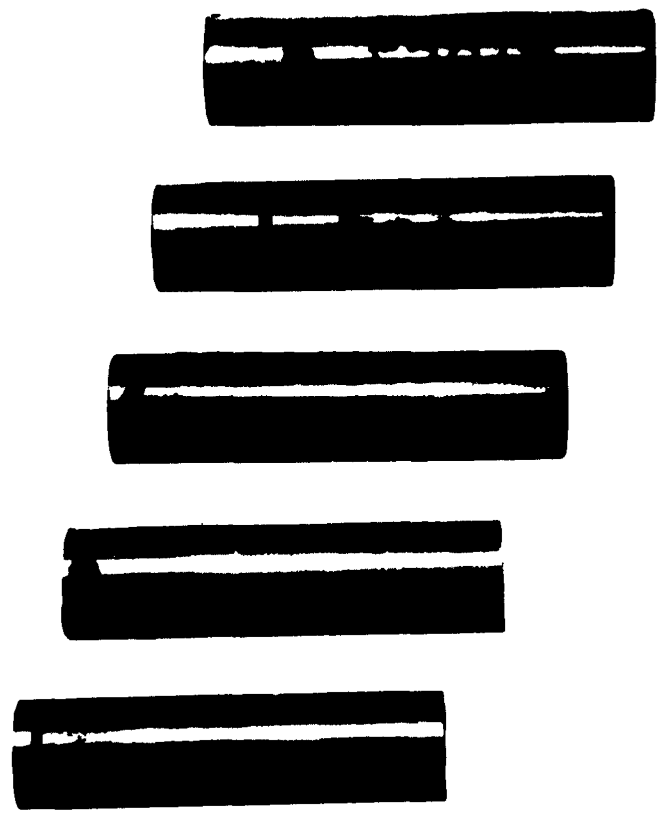

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FIG. 1. Crevice corrosion produced by accelerated method on specimens. 2 thou. Cr plate on FV.520, 4 thou. Cr plate on FV.520, FV.520 soft, FV.520 overaged, and FV.520 peak hardness, respectively.

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